Development of an innovative small sodium-cooled fast reactor
(12) 3D thermal hydraulic transient analysis of RVACS heat removal characteristics

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The capability of the Reactor Vessel Auxiliary Cooling System (RVACS) to remove passively decay heat from the reactor using natural circulation was evaluated performing 3D thermal-hydraulics transient analyses. Especially, the transition to primary coolant natural circulation flow regime during a Loss Of Heat Sink (LOHS) transient and its short-term impact on RVACS air flow have been analyzed using a 3D-CFD calculation code (STAR-CCM+).

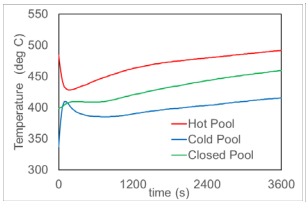
Keywords: Sodium cooled Fast Reactor (SFR), RVACS, Natural circulation, Heat removal, Passive safety, Computational Fluid Dynamics, STAR-CCM+

1. Introduction

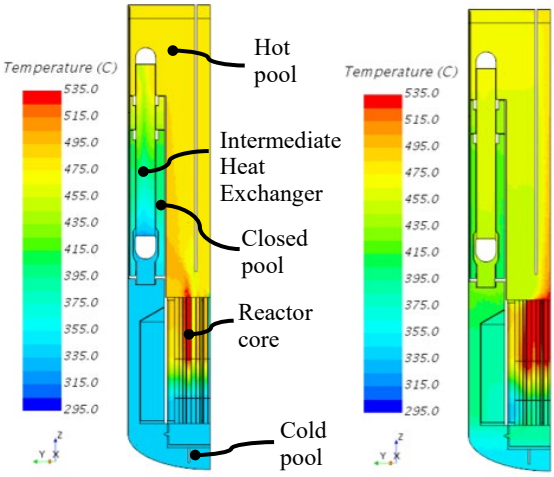
The RVACS is an innovative safety system which removes passively heat from the small modular sodium cooled fast reactor using air natural circulation. The RVACS has been designed based on thermal-hydraulics analyses and tests results conducted overseas in the past. The purpose of this study is to provide a detailed analysis to show the short-term behavior of a thermal-hydraulics transient such as the transition from primary sodium forced circulation to natural circulation using the latest 3D-CFD calculation code.

2. Conditions and methods of study

In order to validate the small modular sodium-cooled fast reactor (PRISM)[1] RVACS heat removal capacity, short-term thermal-hydraulics analyses of a LOHS transient were performed using a detailed and optimized STAR-CCM+ CFD model[2].



Power and primary flow (relative values) | Primary sodium temperatures



Primary sodium temperature distribution (left: 0s (rated power), right: 1200s)

3. Analyses results

In a LOHS transient, a reactor scram causes the primary electromagnetic (EM) pumps to trip. The primary sodium circulation flowrate suddenly decreases and reaches a minimum when the EM pumps driving force reaches zero after a flow coast down period. A primary sodium natural circulation regime then takes place in the reactor and the primary flowrate remains above about 2% of rated flow. The transient goes into a safe core cooling phase in which no sudden nor excessive primary sodium temperature increase was observed. The RVACS heat removal capacity increases gradually as the cold pool sodium temperature rises.

These LOHS transient analyzes will be extended in the future to assess the reliability of the RVACS to remove reactor decay heat and limit the primary sodium temperature rise in the long term.

References

[1] GE, “PRISM Preliminary Safety Information Document” GEFR-00795, 1993 Edition

[2] Abe et al., Atomic Energy Society of Japan, Fall Meeting, 2K17 (2021)